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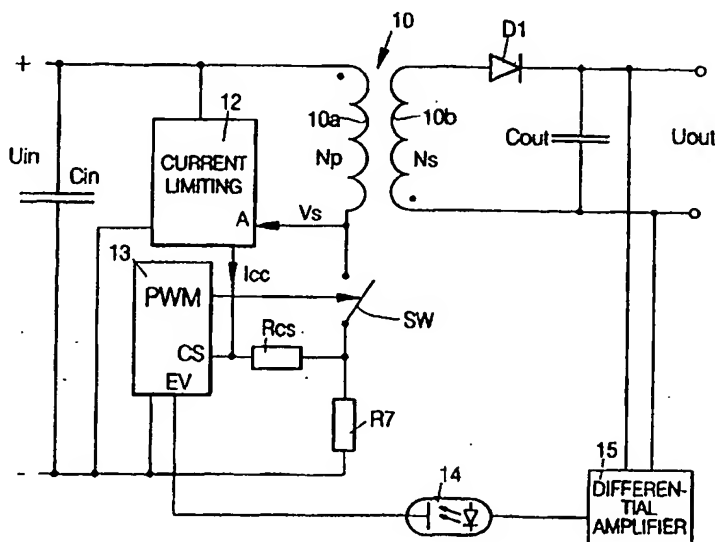
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(54) Title: A METHOD FOR LIMITING THE OUTPUT CURRENT OF A SWITCHED-MODE POWER SUPPLY OF FLYBACK TYPE
IN OVERLOAD SITUATIONS, AND A SWITCHED-MODE POWER SUPPLY OF FLYBACK TYPE

(57) Abstract

The invention relates to a method for limiting the output current (I_{out}) of a switched-mode power supply of flyback type in overload situations and to a switched-mode power supply of flyback type. In accordance with the method, the output current (I_{out}) is limited by means of pulse width modulation (PWM) by adjusting, by means of a control circuit (13) known per se, the ratio of the duration of the ON and OFF phases of the switch (SW) of the primary circuit. In order for the output current not to increase inordinately in overload situations, the voltage (V_s) which is present on the primary side of the transformer (10) and which is dependent on the output voltage (U_{out}) of the power supply is utilized to control a current generator (21), an output current (I_{cc}) of which is used to form a control signal for the control circuit (13).

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A method for limiting the output current of a switched-mode power supply of flyback type in overload situations, and a switched-mode power supply of flyback type

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The present invention relates to a method in accordance with the preamble of the appended claim 1 for limiting the output current of a switched-mode power supply of flyback type in overload situations. The invention also relates to a switched-mode power supply of flyback type in accordance with the preamble of the appended claim 5.

Switched-mode power supplies have a constantly increasing part in the designing of power supplies. This is due to their several advantages, which include for example good efficiency, broad input voltage range and the possibility of achieving compact and light power supplies. Today in switched-mode power supplies, flyback topology is employed to an ever increasing extent (by topology is meant the circuit configuration determining how the power is transferred in the power supply). The greatest advantage offered by the flyback-type power supply is its simple and inexpensive structure which is suitable for use also in multiple-output power supplies. A flyback-type power supply is, however, attended by a certain disadvantage presenting problems particularly if the power supply has multiple outputs. This drawback is the output current that will increase excessively in short-circuit conditions or corresponding overload situations. When the load of a flyback power supply increases so that the control based on sensing of primary current, which is generally used in these power supplies, starts cutting the width of the switch-controlling pulse, the power supply will shift to nearly constant state. When the load is in-

creased and the output voltage decreases, the output current increases. The short-circuit currents are often inordinately high, particularly when the power reserved for the other outputs is transferred to the overloaded output. Separate current-measuring circuits intended for solving the problem will be inordinately costly and require special arrangements, since the control circuit is today usually located in the primary for reasons of economy.

U.S. Patent 4 908 755 discloses one method for limiting the output current of a flyback power supply. The control is effected by controlling the primary current peak value as a function of the input and output voltages. Also in this case the control is realized by means of a rather complicated circuit in which the parameters must be dimensioned so as to be able to simulate the formal interdependence between the input and output voltages and the peak value of the primary current in the flyback power supply.

It is an object of the present invention to eliminate the above drawbacks by means of a solution ensuring as cost-effective practical realization as possible. This is achieved with the method and power supply of the invention, the method being characterized by that which is set forth in the characterizing portion of the appended claim 1 and the power supply being characterized by that which is set forth in the characterizing portion of the appended claim 5.

The idea of the invention is to utilize the secondary voltage reflected through the transformer back to the primary side by forming of this voltage a control signal by means of which the switch-controlling circuit is controlled.

Because of the solution according to the invention, the cooling and foil of rectifiers need not be

over-dimensioned and, furthermore, in the designing of the secondary windings of the transformer, there is no need to safeguard against excessive currents in each winding. Further, possible damage on the load side in the case of a short circuit will be smaller.

In the following the invention and its preferred embodiments will be set forth in greater detail with reference to the examples according to the accompanying drawings, in which

Figure 1 shows a flyback power supply according to the invention,

Figure 2 is a block diagram of the current limiting circuit shown in Figure 1,

Figure 3 shows the interdependence of the control current supplied by the current limiting circuit of Figure 2 on the output voltage of the power supply,

Figure 4 shows a more detailed embodiment of the power supply shown in Figure 1, and

Figure 5 shows the behaviour of the output current and output voltage in a prior art power supply and in the power supply shown in Figure 4.

Figure 1 shows a flyback power supply of the invention, converting a rectified voltage U_i applied to the terminals of an input capacitor C_i to another direct voltage U_{out} which is present in the terminals of the output capacitor C_{out} . The power supply comprises in a manner known per se a transformer 10 through which the power is transferred from the primary to the secondary, a switch SW in the primary circuit chopping the primary current passing through the primary winding 10a, and a control circuit 13 controlling the switch; said circuit controls the output voltage U_{out} by regulating the duty cycle of the switch. The control is effected by means of pulse width modulation (PWM), in other words by adjusting the ratio of the duration of

the ON and OFF phases of the switch. In the secondary circuit, a rectifier diode D1 and an output capacitor Cout are connected in series in parallel with the secondary winding 10b.

5 The flyback power supply operates as follows. When the switch SW is closed (ON), a positive voltage is formed at the point ends of the transformer. In that case, an inverse voltage exists across the rectifier diode D1 of the output, and thus the diode is non-con-
10 ductive. As a result, the secondary current is zero during the ON state of the switch. However, on the primary side the current passing through the switch increases linearly during the ON state. The transformer stores energy in its magnetic flux (air gap) during
15 this phase, and thus the transformer is actually an inductance provided with a secondary winding. When the switch is directed to a non-conductive state (open, i.e. OFF), the energy stored in the magnetic flux of the transformer reverses the voltage of the winding
20 (flyback phenomenon), in which situation the rectifier diode D1 of the secondary side starts conducting and a current starts passing through the secondary winding of the transformer. Unlike the primary current, the secondary current diminishes linearly during the OFF
25 state. At the same time, the secondary current maintains the requisite output voltage across the output capacitor Cout.

 If the load on the output increases, only the duration of the ON state of the switch need to be ex-
30 tended, as a result of which there is enough time for the primary current to increase, and thus during the OFF state the secondary current is respectively higher. The flyback power supply may operate either in the continuous state (there is no time for the secondary
35 energy to become fully discharged after the flyback

state) or in the discontinuous state in which the energy is discharged fully at the end of each cycle. Also such flyback power supplies exist that operate in the continuous and discontinuous state, depending on the load. The power supply according to the present invention may be of any type described above.

The number of turns in the primary winding of the transformer is indicated by the reference N_p and the number of turns in the secondary winding respectively by the reference N_s in the drawing. The switch SW is represented in the figure only as an ideal element illustrating its function; in practice the switch is typically realized with a MOSFET or a bipolar transistor. The control circuit 13 controlling the width of the switching pulse may operate either in the voltage mode based on the output voltage or in the current mode based on the primary current and the output voltage. The majority (about 80%) of the present-day switched-mode power supplies of flyback type utilize current mode circuits (with current mode control a better phase margin for the control is achieved than with voltage mode control). For this reason, the control circuit shown in the embodiment of Figure 1 is a control circuit 13 operating in the current mode and performing the control in response to the voltage information received from the differential amplifier 15 and the current information obtained from the switch. The voltage information is formed by comparing the output voltage to a reference voltage in the differential amplifier and by applying the difference signal to the difference voltage input EV of the control circuit through an opto-isolator 14, for instance. The current information is obtained from the switch SW through a resistor R_{cs} to the current measuring input CS of the control circuit. The information is obtained as a voltage

across the current measuring resistor R7 (having a small value compared to that of the resistor Rcs). The control circuit 13 may be of the type UC 3843 (or some other circuit of the same family), manufacturer Unistat Corporation, U.S.A. Also other manufacturers have corresponding circuits.

The solution according to the invention utilizes the secondary voltage reflected back on the primary side. As is known, in a flyback power supply the voltage Vs across the switch in the OFF state is:

$$V_s = U_{in} + \frac{N_p}{N_s} (U_{D1} + U_{out}) \quad (1)$$

U_{D1} is the voltage across the rectifier diode D1 of the secondary. Since this voltage is small compared with the output voltage U_{out}, it need not necessarily be taken into account. In accordance with the invention, a separate current limiting circuit 12 is incorporated on the primary side, and the voltage across the switch is applied to the input A of said circuit. The output signal (output current) I_{cc} of the current limiting circuit 12 is in turn connected to the current measuring output CS of the control circuit, wherein a control voltage is formed of the current I_{cc} at resistor Rcs for the control circuit 13. The control circuit has a high input impedance, and thus no current passes therein.

The output signal I_{cc} of the current limiting circuit is active only in overload situations, in which case it limits the output current I_{out} of the power supply, as will be set forth hereinafter.

Figure 2 shows the two main blocks of the current limiting circuit 12 of the invention, i.e. a peak value rectifier circuit 22 and a controllable current gener-

ator 21 controlled by said peak value rectifier circuit. The rectifier circuit 22 obtains in its input the voltage V_s referred to above. The current generator in turn is bound to the plus terminal for input voltage U_i and forms in its output a control current I_{cc} that is inversely proportional to the output voltage U_{out} of the power supply. (Since the current generator is bound to the plus terminal for the input voltage U_i , a voltage U_g corresponding to the latter part of formula (1), being independent of the input voltage U_i , acts across it.)

Figure 3 shows the control current I_{cc} emitted by the current limiting circuit 12 as a function of the output voltage U_{out} . When the output current has decreased from its nominal value U_{out1} to a predetermined value $k_1 \cdot U_{out1}$, the current generator 21 starts operating. If the nominal value U_{out1} of the output voltage of the power supply is for example 5 V, the starting point could correspond for instance to 80% of the nominal voltage ($k_1 = 0.8$). Thus the operation of the current generator starts when the output voltage has decreased to 4 V. Furthermore, the current generator is so dimensioned that its maximum current (corresponding to a total short circuit, $U_{out} = 0$ V) is not capable of fully closing the control circuit 13. The control circuit 13 has a threshold value closing the control fully, in which situation no power is obtained from the power supply. The present description employs, by way of example, a typical control circuit threshold value 1 V, corresponding to a current $I_{th} = 1$ mA when the value of resistance R_{cs} is 1 k Ω (the value of resistance R_7 is very small, e.g. 1 Ω , and thus it has no effect). The maximum value of the control current I_{cc} is thus a predetermined portion, e.g. about 75% ($k_2 = 0.75$), of said current threshold value I_{th} which fully

closes the control circuit 13.

Figure 4 shows a more detailed embodiment of the power supply shown in Figures 1 and 2. Figure 4 shows, for simplicity, only the configuration of the primary circuit, since the secondary circuit in this case corresponds to the configuration shown in Figure 1. Further, the feedback loop formed by the differential amplifier and the opto-isolator has been left non-insulated. A Zener diode Z1 and a resistor R3 are connected in series between the input terminals (the input capacitor C_{in} is not shown in Figure 4). A resistor R2 leads from their common node to the base of p-n-p transistor Tr1, to point P1. The emitter of the transistor is connected through resistor R_g to the plus terminal of the input voltage U_i. The collector of the transistor is connected to the common node of the current measuring input CS of the control point 13 and resistor R_{cs}. The base of the transistor is also applied through a resistor R1 to point P of rectifier circuit 22, said point being connected to the minus terminal of the input voltage through capacitor C1. The common terminal of the primary winding and switch SW has also been connected to point P through the series connection of resistor R5 and rectifier diode D2. Resistor R5, diode D2 and capacitor C1 form a peak value rectifier circuit 22, and point P thus constitutes a feed point wherefrom the voltage according to formula (1) above is supplied to current generator 21 formed by Zener diode Z1, resistors R1-R4 and R_g and transistor Tr1. As can be seen from formula (1), this voltage supplied to point P decreases when the output voltage U_{out} decreases (short circuit).

In its other parts, the primary circuit corresponds to the configuration shown in Figure 1, that is, the current measuring input CS of the control circuit

13 is coupled through resistor R_{cs} to the other terminal of the switch, said terminal being connected through resistor R_7 to the minus terminal of the input voltage U_i .

5 In order for the current generator 21 to operate in the manner described above, the resistance values of the circuit must be correctly dimensioned. In the following, the same exemplary values are used as in connection with Figure 3, and it is further assumed that
10 the number of turns in the primary winding of the transformer is 13, the number of turns in the secondary winding is 3, and resistor R_2 biases the Zener diode Z_1 in such a way that the voltage across the Zener diode is 6.2 V. In a balance situation (i.e. in a situation
15 where the output voltage U_{out} has decreased to the threshold (4 V) at which the current generator starts operating), transistor Tr_1 is just becoming conductive, in which situation its base-emitter voltage is about 0 V (0-0.2 V). The current through resistor R_g is still
20 zero, and thus the voltage across resistor R_2 must correspond to the voltage across the Zener diode. If it is assumed that resistance R_2 has a value of for instance 56 k Ω , the current I_2 through resistor R_2 is about 110 μ A. In a balance situation, the voltage at the base of
25 transistor Tr_1 (at point P_1) is $\approx U_{in}$ and the base current of the transistor is zero, and thus the current I_2 can be obtained only through resistor R_1 . Since the voltage across resistor R_1 is ≈ 17.3 V ($13/3 * 4$ V), the value obtained for resistance R_1 is $R_1 \approx 150$ k Ω .

30 When the output voltage U_{out} is higher than 4 V, the current passing through resistor R_1 is respectively higher, and the base-emitter voltage keeps the transistor in the closed state. When the output voltage decreases to 4 V, the control current I_{cc} starts flowing,
35 and the more the output current decreases, the

smaller is respectively the cancelling effect obtained through resistor R1, and thus the control current I_{cc} is respectively higher.

5 In the other extreme situation, there is a total short circuit in the output of the power supply ($U_{out} = 0 \text{ V}$), and thus the voltage of point P is $V_P \approx U_{in}$ (assuming that diode D1 is ideal, i.e. the voltage across it is zero). In that situation, the value of resistance R_g is $R_g \approx 5,7 \text{ k}\Omega$ (assuming that the gain of
10 the transistor is for instance 30) when the desired maximum value of the current I_{cc} is about $750 \mu\text{A}$ (the voltage across resistor R_g is 6.2 V minus the base-emitter voltage of the transistor, which is about 0.5 V , and the voltage across resistor R2, which is about
15 1.4 V).

The value of resistance R3 shall be so dimensioned that the current passing through resistor R2 cannot interfere with the bias of the Zener diode Z1.

20 By changing the ratio of resistances R1 and R2, the limiter threshold ($U_{out} = 4 \text{ V}$) of the current generator can be varied. On the other hand, by changing the value of resistance R_g , various limiting curves can be produced. These curves are described in the following.

25 Figure 5 shows the output current I_{out} of the power supply shown in Figure 4 as a function of the output voltage U_{out} . The balance point is indicated by reference B. The normal operational range is one in which the output voltage U_{out} is maintained at its
30 nominal value U_{out1} (for example 5 V). The angle point L corresponds to the threshold of the control circuit 13 at which the sensing of primary current of the control circuit starts cutting the pulse width and the power supply shifts to nearly constant state in which
35 the interdependence of the output voltage and output

current is illustrated by curve D. However, in accordance with the invention a balance point B of the kind described above is provided, and starting from that point the output current is further limited by means of the control current I_{cc} supplied by current generator 21. When the output voltage U_{out} decreases to the balance point, the output current is thus limited more effectively than heretofore, the interdependence of the output voltage and output current being represented for example by one of the straight lines F1-F5. The direction that said limiting curve will take depends on the value of the resistance R_g . The useful region has been indicated by an arrow H in the figure. If the value of resistance R_g increases to be in excess of the value corresponding to the straight line F5, there is a shift from region H towards curve D, in which situation the solution of the invention is of little utility. On the other hand, if the value of resistance R_g decreases below the value corresponding to the straight line F1, the power supply remains closed. As stated previously, by changing the ratio of resistances R_1 and R_2 the location of the balance point B on curve D can be altered.

Even though the invention has been set forth in the above with reference to embodiments according to the accompanying drawings, it is obvious that the invention is not to be so limited, but it may be varied within the scope of the inventive idea disclosed above and in the appended claims. For example, in practice the power supply may have several outputs, even though the exemplary embodiments set forth above have only one output. Also the detailed realization of the current generator may vary in many ways. The structure described above, however, affords incorporation of the additional features offered by the invention in

switched-mode power supplies of flyback type as economically as possible. It is in principle also possible to utilize the solution according to the invention in connection with a control circuit operating in the voltage mode, even though the invention has been described above only in connection with a circuit operating in the current mode. However, if it is wished to employ a circuit operating in the voltage mode, a control signal suitable for the voltage mode circuit (e.g. UC 3524, manufacturer Unitrode Corporation, U.S.A.) must be formed of the control current I_{cc} . In that case, the solution will be more complex than that disclosed above, and at the same time the advantages of a control circuit operating in the current mode over a control circuit operating in the voltage mode are lost.

Claims:

1. A method for limiting the output current (Iout) of a switched-mode power supply of flyback type in overload situations, according to which method the output current (Iout) is limited by means of pulse width modulation (PWM) by adjusting, by means of a control circuit (13) known per se, the ratio of the duration of the ON and OFF phases of the switch (SW) of the primary circuit, characterized in that the voltage (Vs) which is present on the primary side of a transformer (10) and which is dependent on the output voltage (Uout) of the power supply is utilized to control a current generator (21), an output current (Icc) of which is used to form a control signal for the control circuit (13).

2. A method as claimed in claim 1, characterized in that an output current (Icc) deviating from zero and inversely proportional to the output voltage (Uout) of the power supply is supplied from the current generator (21) when the output voltage has decreased to a predetermined fraction (k1) of its nominal value (Uout1).

3. A method as claimed in claim 1, characterized in that the maximum current supplied by the current generator (21) is maintained below the threshold current (Ith) fully closing the control circuit (13).

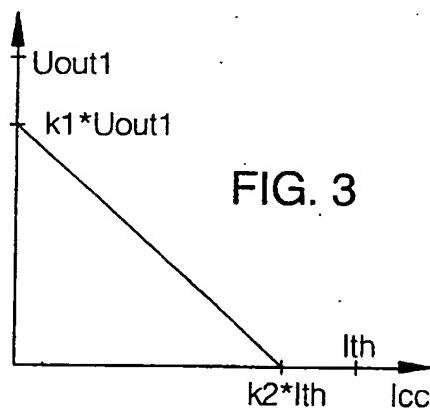
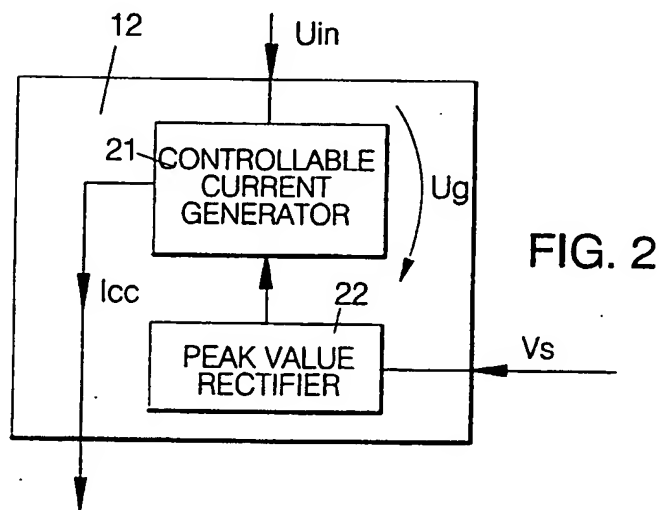
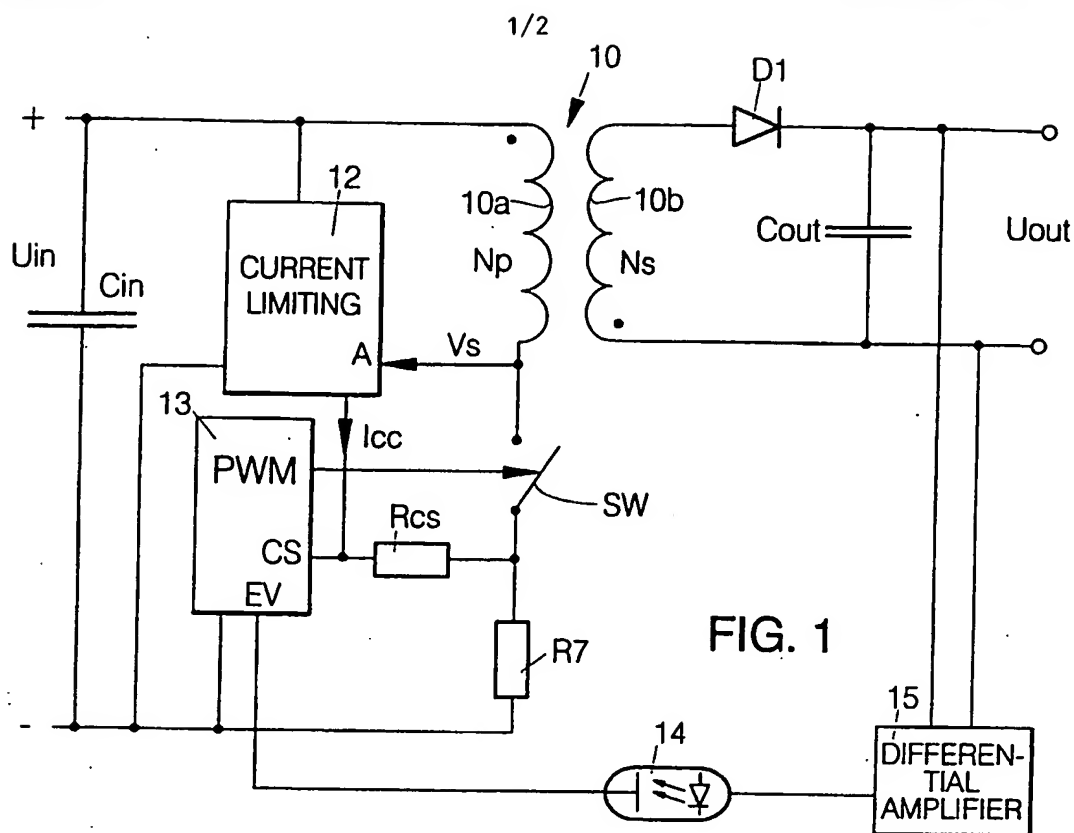
4. A method as claimed in claim 3 wherein the control circuit (13) operates in the current mode, characterized in that the output current (Icc) of the current generator (21) is supplied to the current measuring input of the control circuit (13), to which a signal proportional to the primary current of the transformer (10) is also provided in a manner known

per se.

5. A switched-mode power supply of flyback type, comprising a transformer (10) which is provided with a primary and a secondary winding (10a, 10b) and through which power is transferred from the primary to the secondary, a switch (SW) in the primary circuit whereby the primary current passing through the primary winding (10a) of the transformed is chopped, and a control circuit (13) controlling the switch, said circuit controlling the output voltage (Uout) of the power supply by means of pulse width modulation by adjusting the ratio of the duration of the ON and OFF phases of the switch (SW), characterized in that it comprises means (21, 22) for forming a discrete control signal (Icc) in response to the voltage (Vs) which is present on the primary side of the transformer and which is dependent on the output voltage (Uout) of the power supply, said means switching said control signal to the control circuit (13).

6. A power supply as claimed in claim 5 the control circuit (13) of which is a current mode circuit, characterized in that said means comprise a peak value rectifier circuit (22) to which said voltage (Vs) is connected, and a current generator (21) to which the output of the rectifier circuit is connected, the output of said current generator being connected to the current measuring input (CS) of said control circuit (13).

7. A power supply as claimed in claim 6, characterized in that the current generator (21) is connected to the plus terminal of the input voltage (Uin).



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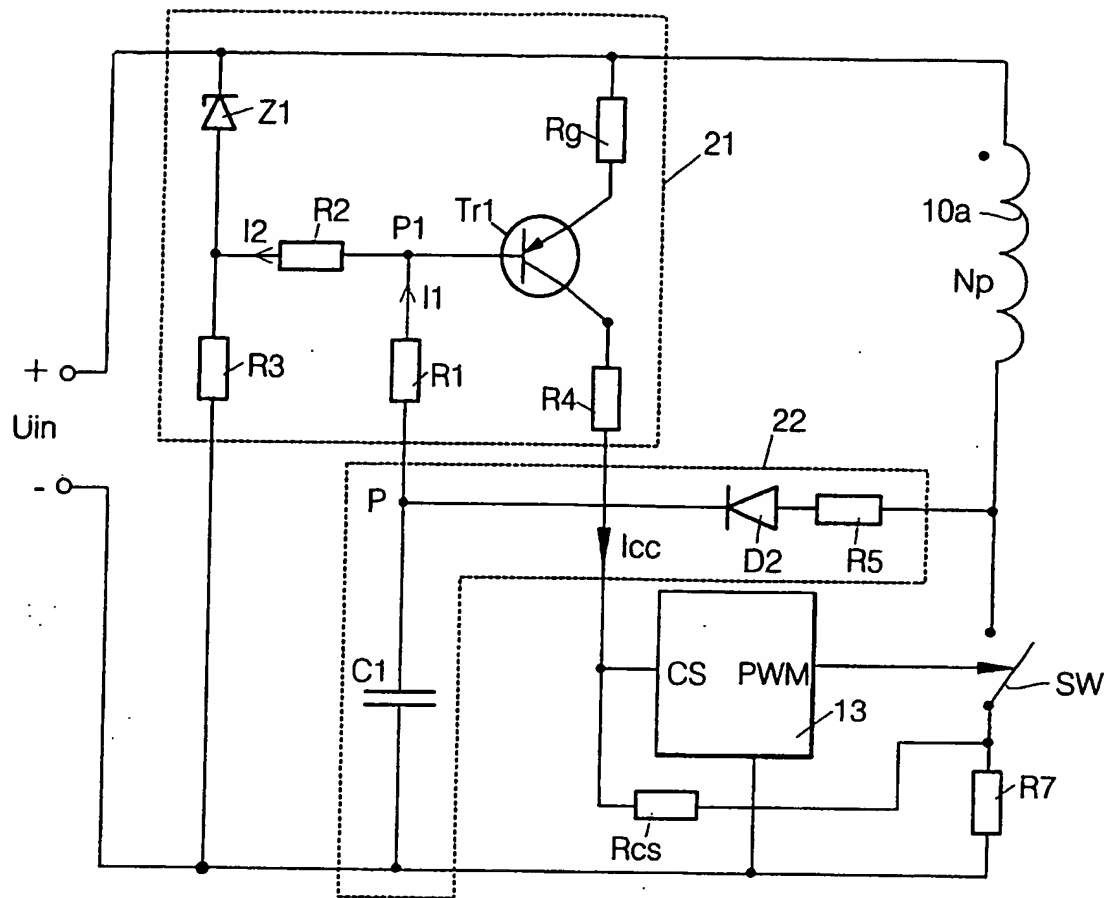


FIG. 4

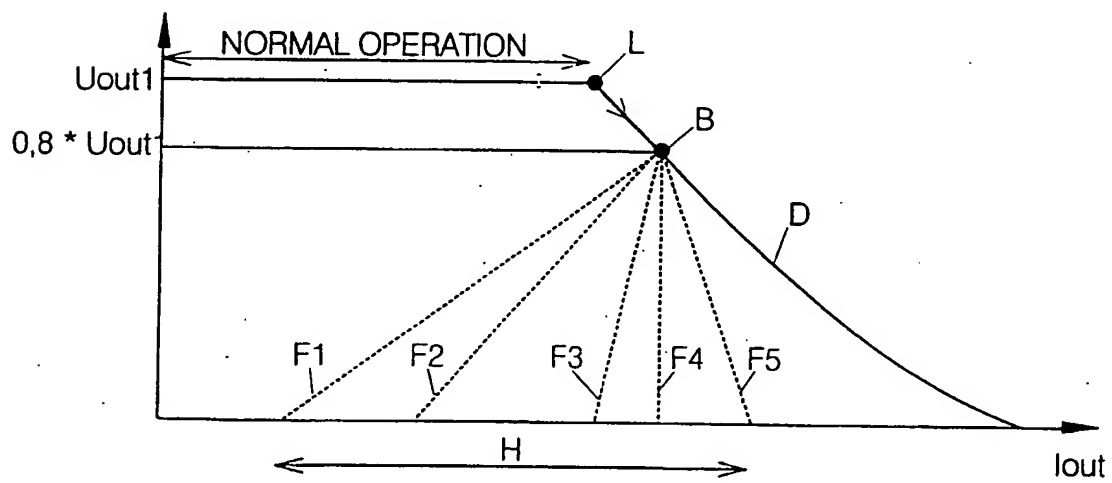


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 94/00090

A. CLASSIFICATION OF SUBJECT MATTER

IPC5: H02M 3/335, H02H 7/122

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC5: H02M, H02H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4908755 (MARTIN FELDTKELLER), 13 March 1990 (13.03.90), abstract	1-7
A	US, A, 4425611 (FINIS C. EASTER), 10 January 1984 (10.01.84), column 2, line 27 - column 3, line 42	1-7

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INTERNATIONAL SEARCH REPORT

Information on patent family members

28/05/94

International application No.

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Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US-A-	4908755	13/03/90	EP-A,B- 0335194	04/10/89
US-A-	4425611	10/01/84	NONE	